INFLUENCE OF HABITAT MODIFICATIONS ON HABITAT COMPOSITION AND ANADROMOUS SALMONID POPULATIONS IN FISH CREEK, OREGON, 1983-88

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INTRODUCTION

Modification of degraded habitats to increase populations of anadromous salmonids is a major focus of management agencies throughout the Pacific Northwest. Millions of dollars are spent annually on such efforts. Inherent in implementing habitat improvements is the need for quantitative evaluation of the biological and physical effects of such work. Reeves et al. (in press), however, noted that such evaluations are rare, making it difficult to assess the true results of habitat work.

While it is not economically possible to thoroughly evaluate every habitat project, it is essential that intensive evaluations be done on selected representative projects. One such evaluation program has been underway since 1982 on Fish Creek, a tributary of the Clackamas River near Estacada, OR. Habitat modification has been done by the USDA Forest Service, Estacada Ranger District, Mt. Hood National Forest with funding provided in part by the Bonneville Power Administration (BPA). The USDA Forest Service, Anadromous Fish Habitat Research Unit, Pacific Northwest Research Station (PNW), Corvallis, OR is charged with: (1) evaluating the biological and physical responses to habitat modifications on a basin scale; and (2) developing a cost-benefit analysis of the program. Preliminary results have been reported in a series of annual publications, Everest and Sedell 1983, 1984 and Everest et al. 1985, 1986, 1987, 1988.

The objectives of this paper are to: (1) report 1988 observations of biological and physical changes in habitat, salmonid populations, and smolt production in Fish Creek, and (2) examine preliminary trends in fish habitat and populations related to habitat improvement over the period 1983-l 988. We have prefaced the trends in the latter objective as preliminary because we believe it could take a minimum of 10 years before the full biological and physical responses to habitat work are realized. We therefore urge caution in interpreting these preliminary results.

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DESCRIPTION OF STUDY AREA

The Fish Creek basin lies in north central Oregon on the west slope of the Cascade Range and drains into the upper Clackamas River (Fig. 1). The watershed is 21 km long, averages approximately 10 km in width, and covers 171 km*. The terrain is steep and mountainous with bluffs in the lower canyons typical of the Columbia River Basalt formation. The valley bottoms are typically narrow with incised stream channels and narrow floodplains.

Fish Creek heads near the summit of the Cascade Mountains at an elevation of about 1,400 m and flows generally north for about 21 km to its confluence with the Clackamas River, about 14 km east of North Fork Reservoir. The channel gradient is steep throughout this distance, generally exceeding 5 percent except for the lower 6 km where gradients average 2 percent. The steep gradient and volcanic geology create a stream with predominately riffle environment and boulder substrate. The mainstem of Fish Creek is 5th order as defined by Strahler (1957) and the annual flow variation near the mouth ranges from 0.5 m^3/sec in late summer to more than 100 m^3/sec during winter freshets.

One major tributary, Wash Creek, a 4th order system, heads in the southwest portion of the Fish Creek basin and enters Fish Creek at km 11. The Wash Creek subbasin covers 36 km* and has a mainstem length of 8 km. The stream heads at an elevation of about 1,200 m. The mainstem habitat of Wash Creek is steep bouldery riffle in a narrow incised channel. Average minimum summer flow is approximately 0.3 m^3/sec.

The Fish Creek basin supports a variety of anadromous salmonids, including summer and winter steelhead trout (Oncorhynchus mykiss), spring chinook salmon (0. tshawytscha), and coho salmon (0. kisurch). Upper areas of the basin contain resident rainbow trout (0. mykiss). However, few resident salmonids are found within the range of anadromous fish and all rainbow trout sampled there were treated as steelhead trout. Approximately 16.7 km of habitat are used by anadromous salmonids, including the lower 4.7 km of Wash Creek. The upper reaches of both Fish and Wash creeks are blocked to anadromous salmonids by major waterfalls, About 20 km on Fish Creek and 8 km of habitat on Wash Creek are unavailable to anadromous salmonids, but provide good resident trout habitat. Culverts have

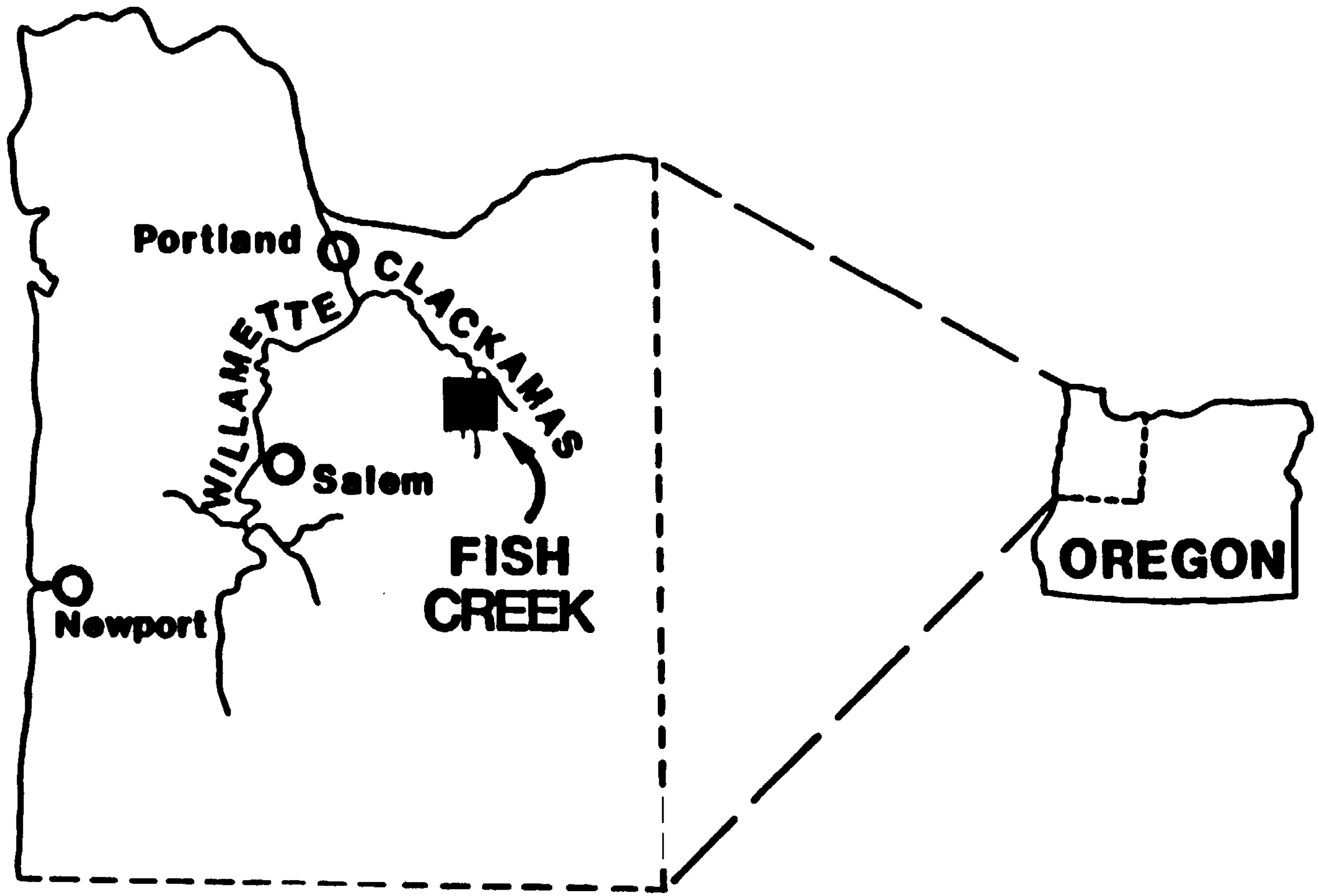

Figure 1. Location of Fish Creek.

blocked access to a total of 2 km of anadromous habitat on three small tributaries to Fish and Wash Creeks. Water temperatures in habitat used by anadromous fish are generally favorable for fish production, ranging from near 0°C at times in winter to about 20°C in most summers. In years with low summer streamflow and high summer temperatures, however, water temperatures can reach stressful levels for salmonids. For example, in early September 1980, temperatures in lower Fish Creek reached 24° C for several consecutive days. Future streamside management in the basin is expected to gradually reduce high summer temperatures and eliminate periodic summer thermal stress for juvenile salmonids as streamside vegetation recovers in areas where land management and natural events have created openings in the riparian zone.

Present habitat conditions in Fish Creek vary significantly from historical conditions. A survey of the Fish Creek basin in 1959 indicated that pools made up about 45 percent of the habitat in the range of anadromous salmonids. A resurvey of the basin in 1965, after the catastrophic flood of December 1964, indicated that pool habitat had been reduced to about 25 percent. Our studies from 1982-88 indicated that pool habitat averaged 15 percent (range 8-22) of total area during those years. The 1964 flood was followed by vigorous logjam removal effort that was probably responsible for the observed decline in pool habitat. The percentage of boulder habitat within the range of anadromous fish increased from 45 to 70 percent in the upper reaches of Fish Creek between 1959 and 1965, and from 25 to 60 percent on Wash Creek. Spawning habitat for anadromous salmonids declined by about one-third during the same time interval.

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HISTORY AND DESCRIPTION OF HABITAT MODIFICATIONS

Construction and evaluation of habitat modifications on Fish Creek began in 1982 as a cooperative venture between the Estacada Ranger District and the PNW. The project was initially conceived as a 5-year effort (1982-l 987) to be financed with Forest Service funds. The habitat modification program and companion evaluation effort were both expanded in mid-1983 when the BPA entered into an agreement with the Mt. Hood National Forest to cooperatively fund work on Fish Creek. Habitat modification work in the basin has been designed to: 1) improve the quantity, quality, and distribution of spawning habitat for coho and spring chinook salmon and steelhead trout; 2) increase low flow rearing habitat for steelhead trout and coho salmon; 3) improve ovenwintering habitat for coho salmon and steelhead trout. An unique aspect of this effort has been the attempt to evaluate improvement projects from a drainage wide perspective.

Projects completed during the first three years of the program were considered prototypes to determine which types were the most effective given conditions found in Fish Creek. Because of the experimental nature of these efforts, only small areas of stream were treated. Types of structures and procedures tested included boulder berms, development of off-channel and side-channel areas, revegetation of selected riparian areas, and introduction of trees into the channel by explosives (see Everest and Sedell 1983, 1984 and Everest et al. 1985 for more detailed descriptions). None of the techniques, except for development of a limited off-channel area (Everest et al. 1987), were considered promising enough for broad application in Fish Creek.

A different approach to habitat modification was adopted in 1986, drawing on experience gained during development of prototype projects. The approach was to intensively treat areas in lower and middle Fish Creek with the objective of increasing habitat complexity, particularly along the margins. Structures built between 1986 and 1988 were combinations of logs and boulders anchored together and to the stream banks with cable and epoxy resin (see Everest et al. 1988 and 1987 for further details). The majority of structures were placed along the stream margin rather than across the channel and were designed to benefit all species and age-classes of anadromous salmonids during all seasons.

Extensive modification of habitats in the basin was initiated in 1986, continued at an accelerated pace in 1987, and was completed in 1988. In 1986 and 1987 more than 300 structures were constructed in lower and middle Fish Creek (Everest et al. 1988). Work in 1986 was concentrated at 3 locations (km 0.0, 0.6, and 7.8) in the basin (Fig. 2). A total of 2 km of habitat was treated intensively. The same type of habitat work was continued in 1987, but a larger area was treated. More than 5.5 km of habitat between km 1.5 and km 7.8 (Fig. 2) was intensively treated with boulder-log structures. Efforts in 1988 were centered in upper Fish Creek and Wash-Creek (Fig. 2). A total of 110 structures were added in these areas. In upper Fish Creek, approximately 50 trees were felled in a 1 km reach to build 33 structures composed of 74 logs and 359 boulders, In Wash Creek, 75 trees were felled in a 1.5 km reach to build 77 structures composed of 144 logs and 593 boulders.

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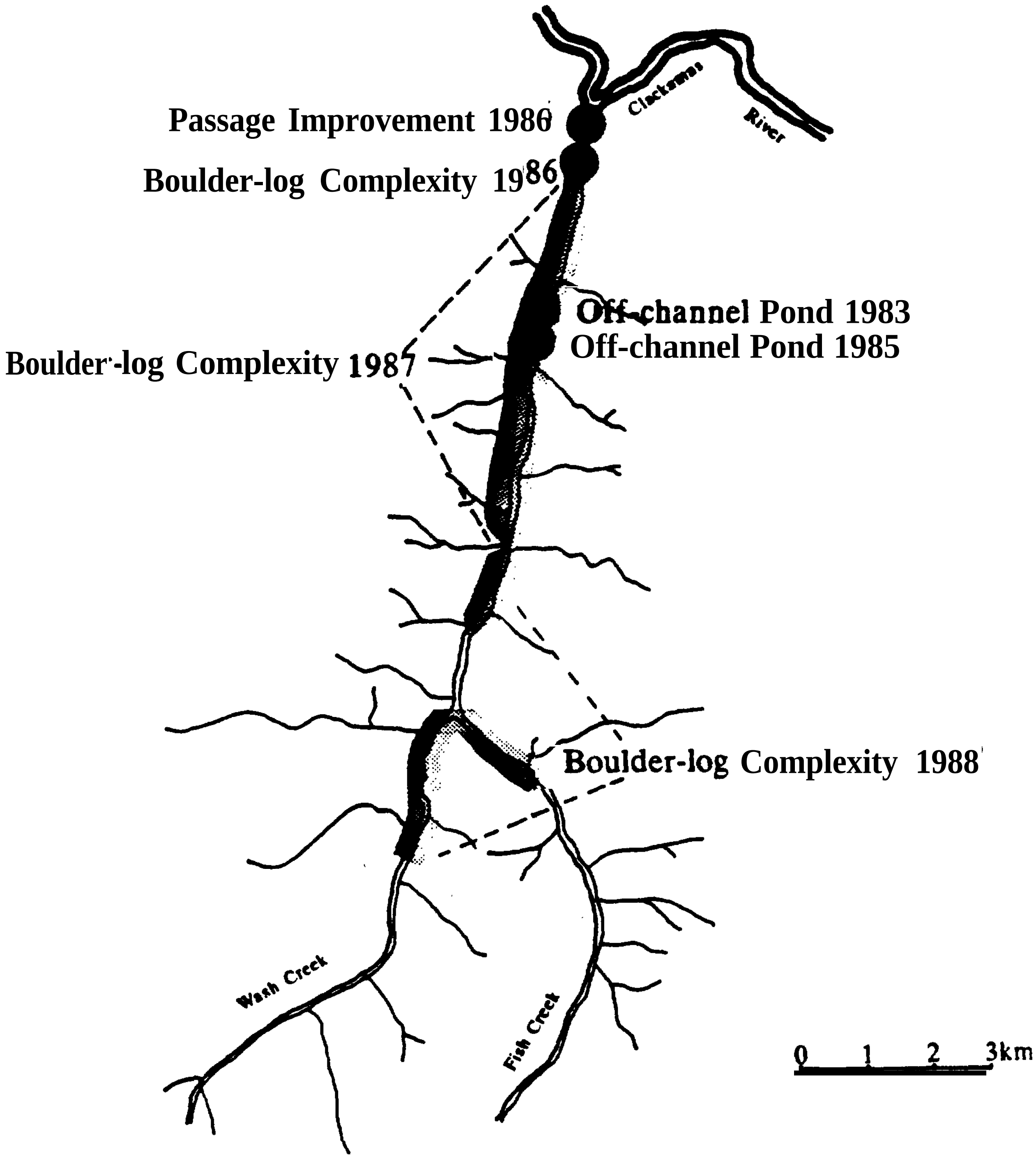

Figure 2. Habitat modification projects completed in the Fish Creek basin.

METHODS AND MATERIALS

Habltat Surveys

Two approaches have been used to estimate the amount of habitat available to anadromous salmonids in Fish Creek in the late summer. From 1982-1984, five 0.5 km sections were sampled, one each on Wash Creek and upper Fish Creek above the confluence of Wash Creek, and three on mainstem Fish Creek between the mouth and Wash Creek. Characteristics of the reaches were believed to be representative of habitat conditions in the basin, Surface area and volume of each habitat unit in each reach were measured. Estimates from each reach were summed and the results extrapolated to the rest of the basin accessible to anadromous fish to estimate total available habitat. Refer to earlier reports (Everest and Sedell 1983, 1984, and Everest et al. 1988) for more detail.

Beginning in 1985, habitat surveys were made following the procedure developed by Hankin and Reeves (1988). It was determined that this technique generated a more accurate estimate of total available habitat and was considered more easily replicated. Five types of habitat, pools, riffles, glides, side-channels (Bisson et al. 1982) and beaver ponds were identified.

Habitat surveys done in 1985-l 987 covered the entire area of the basin used by anadromous fish, rather than the five hag-kilometer reaches used previously. Every habitat unit in the 16.7 km of anadromous habitat was classified according to the five habitat types and its length, width, and mean depth was estimated. Visual estimates of the length, mean width, mean and maximum depth, and amount of spawning gravel were made at each pool, riffle and glide. In addition, the dominant substrate and number of pieces of wood were recorded. Side-channels are rare in Fish Creek so accurate measures of these features were made at every one. Only visual estimates of the area of beaver ponds are made. At every 10th pool, riffle, and glide, accurate measures of length, width at 3 to 4 points along the length of the unit, and depth at 25, 50, and 75 percent of the width, were made. The estimated and measured area and volume of a given habitat type were compared and a correction factor, which reflected the bias introduced by the estimator, was calculated. Visually estimated area and volume of each unit were then multiplied by the correction factor. Total area and volume in each section of the basin were the sums of the areas and volumes of the individual units in that section.

Fish Population Estlmates

From 1982-l 984, fish population estimates for the portion of the basin accessible to anadromous salmonids were made by sampling juvenile salmonids in individual habitat types at 8 locations in the basin. Fish populations were estimated separately for 36 habitat units (one habitat unit is one riffle, pool, side channel, alcove, or beaver pond) and then extrapolated to the basin based on previous estimates of total available habitat. Population estimates were made primarily by electrofishing, using the Moran-Zippen method (Zippen 1958) a multiple pass removal method. Diver counts of fish were made in riffles and pools that were either too swift or too deep for effective electrofishing (about 50 percent of the area sampled). Refer to Everest and Sedell 1983, 1984, and Everest et al. 1985 and 1986.

Beginning in 1985, fish numbers were estimated following the technique of Hankin and Reeves (1988). This technique utilizes direct observation with a mask and snorkel, and by electrofishing. A team of 2-3 divers, the number depending on the size of the unit, count all salmonids in a selected unit. On a certain fraction of the units that are snorkled, population estimates are made by electrofishing. The population estimate (Moran-Zippen (Zippen 1958)) is considered an accurate estimate of the true number of fish in a unit. A correction factor similar to that developed for habitat estimates was generated to compensate for diver bias, Units to be sampled by divers were systematically determined. The fraction and number of units of each habitat types that were sampled and the number of units in which accurate population estimates were made in 1985-l 988 are shown in Table 1. More detailed description of the methodology is contained in Everest et al. 1985, 1986, 1987, and 1988.

Table 1. Number and fraction of different habitat types sampled for fish populations in Fish Creek, 1985-l 988.

Year	Habitat type	Total no. of units identified	Snorkeled No.	Snorkeled Percent	Electroshocked No.	Electroshocked Percent
1985	Pool	**100**	14	14.0	14	14.0
	Riffle	201	18	8.9	15	7.5
	Glide	116	11	0.9	0	0.0
	Side channel	13	25	7.7	6	2.6
1986	Pool	178	30	16.9	5	2.8
	Riffle	234	25	10.7	6	2.6
	Glide	126	22	17.5	5	4.0
	Side channel	1	0	0.0	0	0.0
1987	Pool	**94**	52	55.0	10	10.6
	Riffle	140	23	16.4	5	3.6
	Glide	103	26	22.3	9	8.7
	Side channel	5	0	0.0	0	0.0
1988	Pool	77	**39**	50.6	8	10.4
	Riffle	119	31	26.1	10	8.4
	Glide	102	27	24.0	8	7.8
	Side channel	5	4	80.0	0	0.0

Estimates of Smolt Production

Smolt production of steelhead trout and coho and chinook salmon in 1985-l 988 was quantified by use of a floating smolt trap. In 1980, the trap was operated from 16 March to 10 June. The trap (Fig. 3) is a catamaran configuration consisting of two 0.6 x 0.6 x 7 m pontoons straddling a traveling screen powered by a paddle wheel. The 1.5 m wide traveling screen (4 mm mesh) is fitted with seven 50 x 50 mm baskets that extend across the entire width of the screen at equal intervals. The screen can be lowered into the water to any desired depth between the surface and within about 20 cm of the bottom. The paddlewheel is powered by the streamflow passing by the trap and turns the traveling screen at speeds up to 15 **cm/sec.**

This trap was fished 0.3 km upstream from the mouth of Fish Creek by positioning it with cables in high velocity water at the stream thalweg (Fig. 4). Downstream migrant salmonids, moving primarily at night, are impinged on the subsurface portions of the traveling screen and baskets move continuously

Figure 3. Modified Humphrey trap used to sample smolts on Fish Creek.

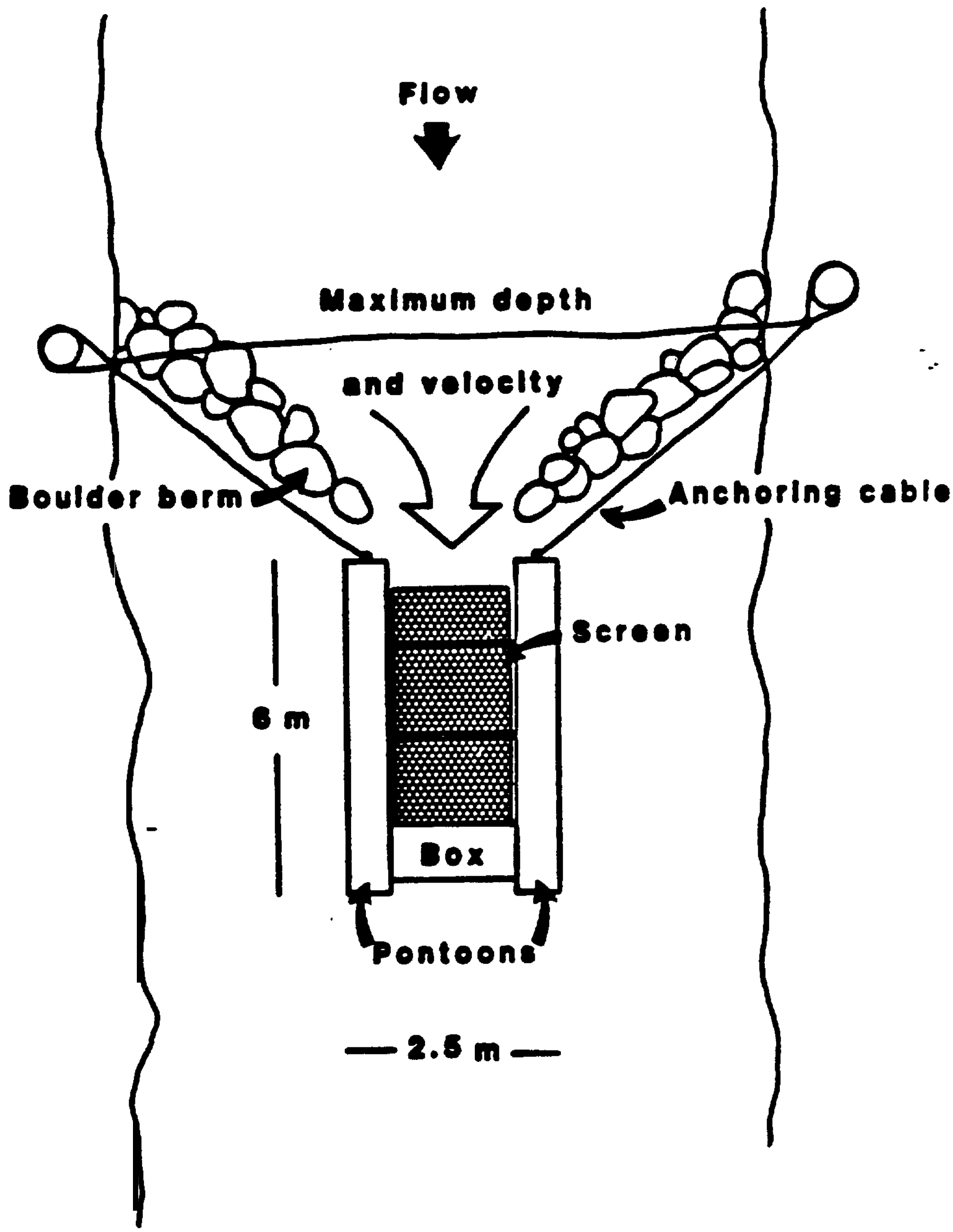

Figure 4. Schematic diagram of Humphrey trap in modified position.

upward. As the screen rotates around the upper axle, the fish drop by gravity into a holding box that can maintain more than 100 fish for several days.

The trap samples only a portion of the cross-sectional area of the stream and so its efficiency must be calibrated. The efficiency is determined by releasing a known number of marked migrants upstream of the trap and assessing the capture rate of these fish. Since capture efficiency changes with flow level, efficiency checks must be made at all levels of flow experienced while the trap is fishing. The trap must be tended daily or twice daily when large numbers of fish are migrating downstream.

Smolts leaving the eastside off-channel pond at km 3 were captured in a trap at the head of the fish ladder at the pond outlet. A rotating drum screen diverts all downstream migrants into a screen trap box adjacent to the ladder. Smolts are also captured at a similar ladder and trapping device located at the outlet of the westside off-channel pond located at km 3.5.

* * *

RESULTS

Available Habitat 1988

The amount of habitat available to anadromous salmonids in late-summer 1988 was 12 percent greater than 1987, which was the lowest amount since the study began (Everest et al. 1988) (Table 2). This increase observed in 1988 was associated with higher flows (Fig. 5). The proportion of habitat types were similar in 1987 and 1988 (Table 2). Riffles were the dominant habitat type found, accounting for 55.8 percent of the total.

The distribution of salmon was more restricted in 1988 than in the previous year. In 1987, both chinook and coho salmon were observed in the middle third of the mainstem (Everest et al. 1988). However, salmon were primarily restricted to the lower third of the mainstem in 1988. Very few coho salmon and no chinook salmon were observed in the middle section in 1988. The reason for this restricted distribution most likely varied with species. Low flows in the fall reduced access of adult chinook salmon to Fish Creek. Coho salmon distribution was probably diminished by a combination of decreased adult returns (as indicated from counts of North Fork Dam) and low flows. Reduced number of spawners would diminish competition for spawning sites and probably allowed fish to spawn in a more limited area. Low flows at the time of spawning probably also restricted distribution by reducing access.

About one-third of the habitat in Fish Creek had been influenced by the modification effort by the end of 1988 (Table 3). The lower section of Fish Creek received the most effort, with about 47.5 percent of the area being modified.

Table 2. Area (m^2) of habitat available to anadromous salmonids on Fish Creek, September 1982-1988.

							Habitat Types						
Year	Pools	%	Riffles	%	Glides	%	Side channels	%	Alcoves	%	Beaver[1] ponds	%	Total
1982	18,450	4.3	138,590	84.6	--	--	4,250	2.6	2,270	1.4	190	0.1	163,750
1983	20,850	8.4	219,360	88.0	--	--	6,200	2.5	2,450	1.0	300	0.1	249,160
1984	19,180	10.2	161,700	85.7	--	--	5,320	2.8	2,280	1.2	270	0.1	188,750
1985	26,380	18.3	93,700	65.1	21,030	14.6	2,580	1.8			190	0.1	143,950
1986	27,470	16.2	114,400	67.5	27,380	16.2	0 [2]	0.0			190	0.1	169,440
1987	29,660	22.1	79,700	59.3	23,980	17.8	940 [3]	0.7			190	0.1	134,470
1988	32,590	21.4	84,970	55.8	33,370	21.9	1,050	0.7			190	0.1	152,170
Mean	24,940		127,423		26,440		3,457		2,333		217		171,670

[1] Does not include enhanced off-channel ponds.
[2] All side channels were dry when habitats were quantified in September.
[3] All side channels nearly dry in 1988 and were not sampled for fish.

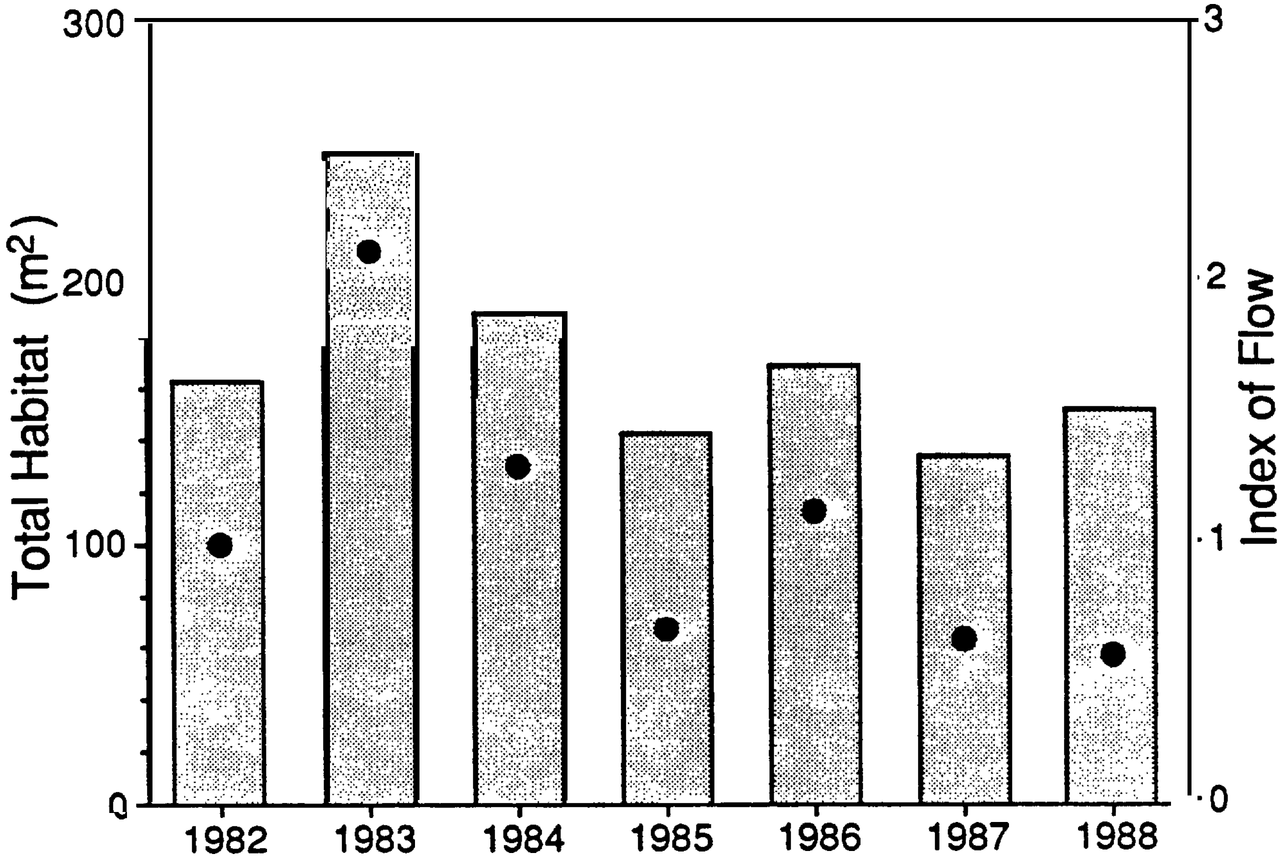

Figure 5. Relationship between amount of rearing habitat available to anadromous salmonids on Fish Creek and an index to streamflow during the sampling period.

Table 3. Percent of habitat units modified in Fish Creek through 1988.

	Unmodified units		Modified Units		
	Area (m^2)	Percent	Area (m^2)	Percent	Total
Lower Fish Creek	37,458	52.5	33,958	47.5	71,416
Mid Fish Creek	25,125	82.3	5,402	17.7	30,527
Upper Fish Creek	8,147	78.2	2,271	21.8	10,418
Wash Creek	30,200	76.2	9,412	23.8	39,612
Total	100,930	66.4	51,043	33.6	151,973

Offshore Recovery of Coded Wire Tagged Coho Salmon.

During April, May, and June 1987, 79 juvenile coho salmon leaving the Fish Creek rearing pond as smolts were marked with coded wire nose tags. During the same time period 719 coho smolts leaving Fish Creek were also marked with coded wire tags. Three of the marked fish were captured in the ocean troll fishery off the coast of Oregon in the summer of 1988 (Fig. 6). The fish ranged from 53.0 cm to 64.3 cm and were caught by commercial trolling vessels between DePoe Bay and Winchester Bay (Table 4). Two of the recaptured fish were from the rearing pond and one was from Fish Creek. The first recoveries of tagged Fish Creek coho indicate that the upper Clackamas stock moves south after entering the ocean at the mouth of the Columbia and remains vulnerable to the Oregon troll fishery.

Table 4. Recoveries of coded wire nose tagged coho salmon from Fish Creek, 1988 in the offshore commercial fishery.

Date caught	Location landed	Length (cm)
16 July, 1988	DePoe Bay	56.1
21 July, 1988	Winchester Bay	64.3
09 August, 1988	Newport	53.0

Figure 6. Locations where coded wire tagged coho salmon from Fish Creek were captured in the off-shore commercial fishery.

Smolt Production

Coho Salmon

An estimated 3050 coho salmon smolts were produced from Fish Creek in 1988 (Table 5). Of these, 2375 (77.9 percent) originated from the mainstem and 675 (22.1 percent) from the off-channel ponds. Mainstem production was 38 percent higher than the estimated mean number produced per year in the previous three years (mean 1715).

Table 5. Estimated number, origin, and estimated over-winter survival of coho salmon smolts leaving Fish Creek, Oregon, 1985-l 988.

Year	Mainstem Fish Cr. No.	Mainstem Fish Cr. % Total	Eastside Pond No.	Eastside Pond % Total	Westside Pond No.	Westside Pond % Total	Estimated Overwinter Survival No.	Estimated Overwinter Survival % Total
1985	2,606	84.1	493	15.9	[1]		3,099	31.4
1986	1,175	49.6	1,196	50.4	[1]		2,371	9.8
1987	2,579	67.8	1,234	32.2	[1]		3,831	38.3
1988	2,375	77.9	264	8.7	411	13.4	3,050	6.3

[1] Pond was created in 1985 but did not become operational until 1987.

The absolute number of smolts produced in 1988 was high but over-winter survival based on smolt emigrants was 6.3 percent, the lowest observed since the evaluation began. We believe this was probably due to the dynamic nature of over-wintering habitat in Fish Creek. Coho salmon numbers in the summer of 1987 were 37,800 (Everest et al. 1988), which is the largest number observed since the study began. Flows in Fish Creek in the late fall and early winter of 1987 were extremely low. Previous work (Everest et al. 1987) found that coho salmon used areas along the stream margins during the winter. These areas were generally sites of boulders and debris collections which sat above the low water level. The amount and quality of habitat available to juvenile coho salmon is probably related to water levels at the time winter temperatures decrease to F° C. When flows are high before temperatures drop, fish are able to use areas higher on the margin and appear to have greater overwinter survival. In 1988, many of these areas were inaccessible for part or most of the winter and coho salmon may have been forced from the system or died.

Smolt production from the off-channel ponds (Everest and Sedel11984 and Everest et al. 1987) was extremely low in 1988. Production from the older east-side pond was the lowest recorded since it became operational in 1984. Only 264 smolts left the pond. The new pond on the west-side of Fish Creek produced 411 smolts. This represented 8.7 percent and 13.5 percent, respectively, of the total coho salmon smolt production for the system. This is in contrast to previous years when the older pond contributed as much as 50 percent of the coho salmon smolts leaving Fish Creek (Table 5).

The reason for the low numbers of coho smolts produced in the ponds was becasue of high mortality from bacterial kidney disease (*Renibacterium* salmoninarum) (BKD). The ponds were stocked with infected fish from the ODFW Clackamas River hatchery. The fish had been held and treated at the hatchery for red mouth (*Yersinia ruckeri*), but were considered healthy at the time of stocking. Ten thousand fish were put in the east-side pond and 5000 in the west-side pond. Smolts leaving the ponds in the spring were in poor condition. They were usually very thin and had bulged eyes. Examination by ODFW pathologists at Oregon State University found that the fish were infected with BKD, a very virulent disease.

Because of the fear of establishing pathogens in the ponds, water into the ponds was turned off in the summer of 1988. It was hoped that if the ponds dried up, chances of future contamination would be reduced. Also, no fish were stocked in the pond and as a consequence no smolt production is expected from the ponds in 1989.

Steelhead Trout

Fish Creek produced an estimated 3118 steelhead trout smolts in the spring, 1988. Almost all of these smolts (99.4 percent) originated in the mainstem. The remainder (18 fish) were produced in the east-side off-channel pond. This is the lowest estimated production of steelhead trout smolts leaving Fish Creek since smolt production has been monitored (Table 6). It was less than half the **estimated smolt numbers from 1987 and was 56 percent of the four year average (Table 6).**

Table 6. Estimated number and over-winter **survial** of steelhead trout smolts leaving Fish Creek, Oregon, 1985-l 988.

Year	Estimated number	Estimated over-winter survival (%)
1985	7,473	70
1986	3,781	40
1987	7,600	92
1988	3,100	42
Mean 5,489 (± 2,382)		

Over-winter survival of 1 + pre-smolt steelhead was estimated to be 42 percent (Table 6). This rate was well below the estimated survival rate of 92 percent the previous year. We do not know the exact reason for this low rate of survival but believe it is related to the timing and magnitude of high flow events in the winter. In Fish Creek, there was a IO-12 year high flow event in early December 1987. This was more than a month earlier than commonly occurs. The effects on fish were probably exacerbated by extremely low flow conditions that existed in November. Mean flow on the Mollala River (which has a USGS staff gage and is used as an indicator of flows for Fish Creek), was 98 cfs, which was less than 10 percent of the average for the previous three years. With such low flow, less habitat would have been available to fish at the time of entering the substrate. That which was available was closer to the thalweg and was probably subject to greater scour than more protected areas closer to the bank.

Juvenlle Numbers and Densities

The estimated number of juvenile salmonids in Fish Creek in September, 1987 was 14 percent less than in 1986 and about 5 percent below the average number for the period 1982-l 987 (Table 7 and Appendix 1). The structure of the salmonid community was similar to that observed in previous years, however. Steelhead trout accounted for more than 90 percent of the estimated total numbers (Table 7).

Table 7. Estimated numbers of juvenile anadromous salmonids in Fish Creek, September, 1982-l 988, and percent of total population.

Year	0+ Steelhead Number	0+ Steelhead Percent	I+ Steelhead Number	I+ Steelhead Percent	Coho Salmon Number	Coho Salmon Percent	Chinook Salmon Number	Chinook Salmon Percent	Total
1982	87,810	78.7	21,680	19.4	1,910	1.7	120	0.1	111,520
1983	60,030	66.5	21,670	24.0	7,430	8.2	1,140	1.3	90,270
1984	88,060	73.1	23,800	19.8	8,290	6.7	290	0.2	120,440
1985	115,770	76.9	18,500	12.3	11,980	7.9	4,350	2.9	150,620
1986	117,870	82.8	20,670	14.1	3,560	2.5	200	0.1	142,300
1987	53,400	47.0	15,970	14.1	37,880	33.4	6,290	5.5	113,540
1988	79,500	81.5	14,460	14.8	3,550	3.7	0	0	97,510
Mean	86,063	72.4	19,536	16.9	10,657	9.21	1,770	1.5	101,809

Coho Salmon

The estimated number of coho salmon in Fish Creek in September, 1988 was 3547 (Table 7). This is less than 10 percent of the estimated number found in September, 1987. The reason for this decline is not readily apparent. The most obvious explanation appears to be the reduced escapement of adult coho salmon above North Fork Dam (Table 8). Adult numbers in 1987-1988 were about one-fourth of the 1986-1987 numbers. Everest et al. (1988), however, speculated that the relation between adult escapement over North Fork Dam and juvenile coho salmon numbers in Fish Creek was not necessarily very strong. It is therefore questionable how much of the decline can be attributed to differences in adult numbers.

Chinook Salmon

No juvenile chinook salmon were observed in Fish Creek in September, 1988 (Table 7). This contrasts with 1987, when there were more than 6,000 chinook salmon estimated to be present. The most obvious explanation for this probably is lack of adult escapement to Fish Creek. The estimated number of adult spring chinook salmon passing North Fork Dam was the 3,089 (Table 8) the second highest count since the study began in 1982. The mouth of Fish Creek was modified in 1986 to facilitate passage. However, it would appear that water levels were so low during the time spring chinook spawn that adults could not make their **way** into Fish Creek.

Table 8. Counts of adult anadromous salmonids at North Fork Dam, 1981-82 to 1986-88.

	Steelhead trout			Coho salmon		Spring chinook salmon	
Year	Summer	Winter	Total	Total	Jacks	Total	Jacks
1981-82	4,138	1,446	5,584	1,282	(112)	3,119	(209)
1982-83	1,948	1,099	3,047	2,949	(405)	2,685	(102)
1983-84	11,062	1,238	12,300	1,599	(78)	2,835	(87)
1984-85	5,549	1,225	6,674	694	(83)	1,693	(140)
1985-86	7,422	1,432	8,854	3,315	(592)	1,960	(163)
1986-87	4,367	1,282	5,639	4,376	(214)	1,214	(291)
1987-88	7,695	1,318	9,013	1,202	(131)	3,089	(51)
Mean	6,026	1,291	7,304	2,202	(230)	2,371	(149)

Steelhead Trout

0+ - The estimated number of 0+ steelhead trout in Fish Creek was 41 percent greater in 1988 than in 1987. This was the only age-class or species of salmonids to show an increase in numbers from the previous year. It appears that this increase is attributable, at least in part, to the increase in the number of adult steelhead trout, both summer and winter fish, returning to the Clackamas River system and the amount of habitat available in late summer. Adult numbers were 60 percent higher in 1988 than in 1987. How much of the increase in juvenile numbers is attributable to this increase in adults is questionable, however. The correlation between adult numbers at North Fork dam and estimated juvenile numbers in Fish Creek is only moderate, r = 0.42 (Fig. 7). Everest et al. (1988) found a similar relationship between juvenile numbers and number of winter adult steelhead trout.

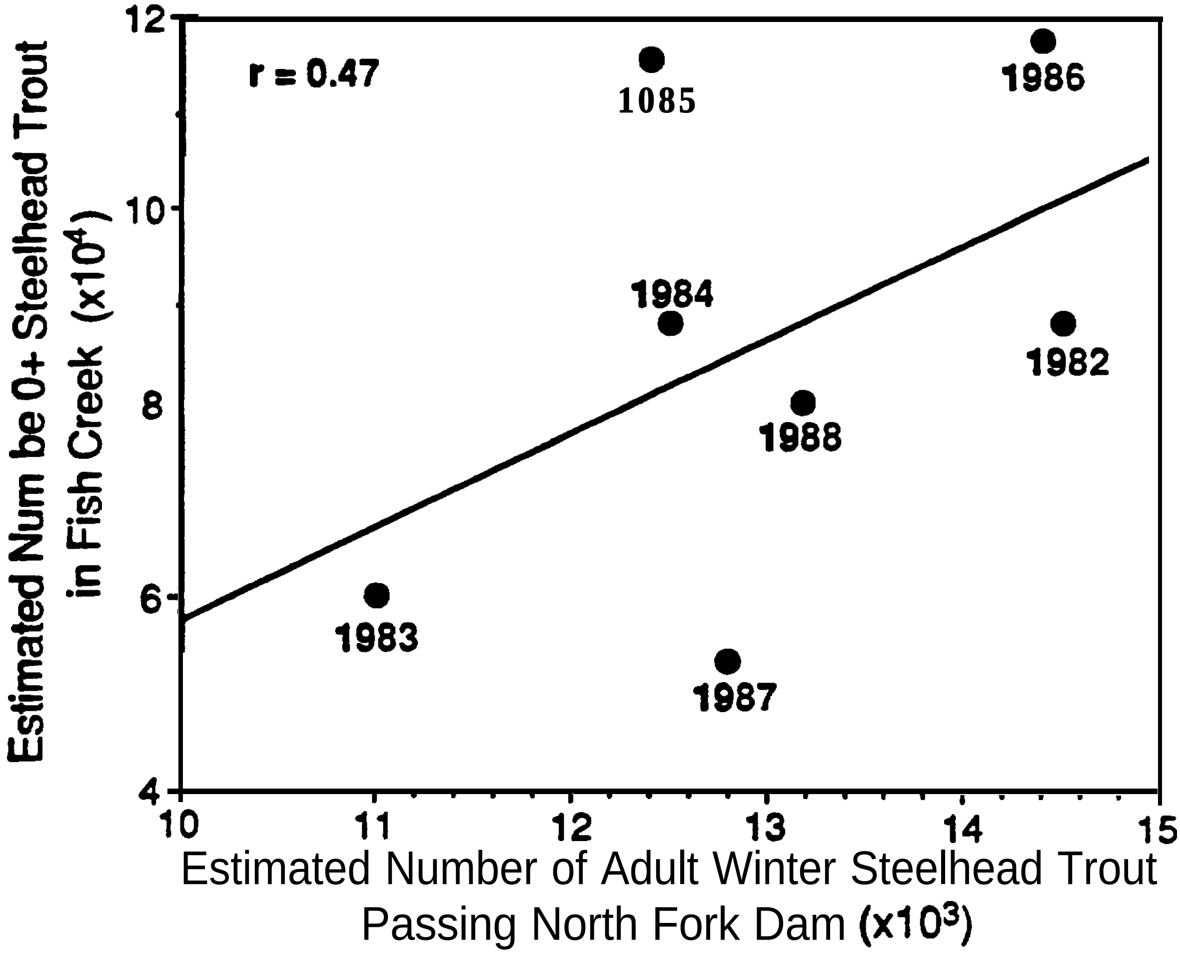

Figure 7. Relationship between estimated number of adult steelhead trout passing North Fork Dam and the estimated number of 0+ steelhead trout in Fish Creek the following year.

The amount of **habitat** in Fish Creek in September, 1988 was 12 percent greater than the previous year (Table 2). Pool and glide habitat increased 10 percent and 40 percent from 1987, respectively. These habitats have supported the greatest densities of 0+ steelhead trout in previous years (Everest et al. 1987).

l+ - There was **a** 9.5 percent decrease in the estimated number of 1 + steelhead trout in Fish Creek in 1988 compared to 1987. Everest et al. (1988) found a strong correlation between numbers of 1 + steelhead trout and low summer streamflow. They concluded that the abundance of 1 + steelhead trout was related to the amount of available habitat, The trend in 1988 appears to run counter to this; the amount of habitat increased but fish numbers declined. The reason for this deviation is not apparent. One factor that may be responsible was the low number of 0+ steelhead trout present in 1987 (Everest et al. 1988). Survival over the year was apparently good, 27 percent. However, the small number of 0+ fish was probably an important factor in determining the number of 1 + fish.

Trends 1982-l 988

Habitat

The amount of habitat available to anadromous salmonids in late summer each year in Fish Creek has varied widely since the study began. It has ranged from 249,000 m^2 in 1983 to 134,470 m^2 in 1987 (Table 2). This fluctuation is dependent on the water year, with the most habitat available in the years of higher flow (Fig. 5). The years when the most habitat was available were in the period 1982-l 984 (Table 2) prior to the initiation of the intensive modification program. This also coincides with the years of highest flows during the period when the stream was sampled. Since the intensive modification effort was started, flows have been lower (compared to the 1982-84 period) and the amount of available habitat less.

Since the habitat modification effort began in 1986, approximately 33 percent of habitat units in Fish Creek have been affected (Table 3). In the lower section, 47.5 percent of all units and 60 percent of all pools have been modified by the boulder-log and log complexes. Habitat work has more than doubled the volume of woody debris in the channel (Everest et al. 1988). Most of the wood is in clumps at the margins of the stream.

Habitat modification has changed the habitat composition in Fish Creek. There has been an increase in the amount and percent of pool and glide habitat, with percent of pool habitat almost doubling (Table 2). There has been a corresponding decline in the proportion of riffle. Surveys made in 1959 found that pools accounted for 45 percent of the habitat in Fish Creek. That fraction was reduced to 25 percent following the 1964 flood. It appears that the modification program has been successful in restoring pool habitat. These early surveys did not include a glide category and glides were probably classified as pools. If this is true, pools and glides in 1988 accounted for 43.3 percent of the habitat in Fish Creek. This is close to the estimated fraction found in 1959.

Smolt Production

Coho Salmon

Malnstem. Estimated production of coho salmon smolts from the mainstem of Fish Creek was highly variable between 1985 and 1988 (Table 5). The mean number of smolts leaving Fish Creek annually during that period was 1,889 (+716). There is a large amount of variability in the two years prior to intensive habitat manipulations (1985-86) and in the two years of habitat manipulation (1987-88). Smolt production was highest in 1985 and lowest in 1986 (Table 5). This would suggest that production of coho salmon smolts in Fish Creek is inherently variable.

Smolt production was also quite variable during the two years of intensive habitat modification (Table 5). Smolt production was lowest in 1987, when most of the modification effort was done in lower Fish Creek. Lower Fish Creek is the portion of the system where most coho salmon rear. It increased in 1988, but was less than the highest estimated number of smolts that were produced in the pre-implementation period. The large variability observed the last two years makes it impossible to discern the effects of the modification program to date. Effects may become clearer as more data are collected.

The reason for the large variability in coho salmon smolt production in Fish Creek is not readily apparent, particularly with only four year's data. One factor that could influence smolt production is the number of juvenile coho salmon in Fish Creek the summer prior to smolt migration. The correlation between smolt numbers and numbers of juveniles is moderate, r = 0.44, however (Fig. 8). Researchers in Washington also found poor relationships between juvenile numbers and smolt numbers (D. Seiler, Washington Department of Fisheries, Olympia, WA).

In contrast, production of coho salmon smolts in coastal streams in Washington is also strongly related to amount of habitat available during the late-summer low flow period (D. Seiler, Washington Department of Fisheries, Olympia, WA). The correlation between coho smolts and the amount of late summer habitat available to coho in Fish Creek is strong, r = 0.872 (Fig. 9).

Other factors may also be responsible for the large variability in coho salmon smolt production in Fish Creek. Swales et al. (1986) reported that in cold interior British Columbia streams, coho salmon densities during the winter were greatest in side-channels. They suggested that these were preferred because side-channels had large amounts of low velocity habitat. Off-channel and sidechannel habitats for over-wintering are limited in lower Fish Creek.

The number, magnitude, and timing of high flow events may also be related to over-winter survival of coho salmon, and ultimately smolt production, in Fish Creek. Everest et al. (1986) suggested that a large winter storm event (usually a rain-on-snow event), combined with a relatively cold winter might account for a large portion of the observed variation in smolt numbers. Timing of high flow events relative to the availability of winter habitat in the fall is probably also very important. Everest et al. (1987) found juvenile coho salmon using large wood-boulder complexes located higher on the stream margins. These habitats are not available until water levels rise in the late fall or early winter. If a high flow event occurred before these habitats were accessible, we would predict that mortality or movement out of the basin of coho salmon would be high. An example of this would be the winter of 1987. Water levels were extremely low during most of the winter but there were a series of high flow events over the winter. Over-winter survival for that year was 6.3 percent, the lowest survival

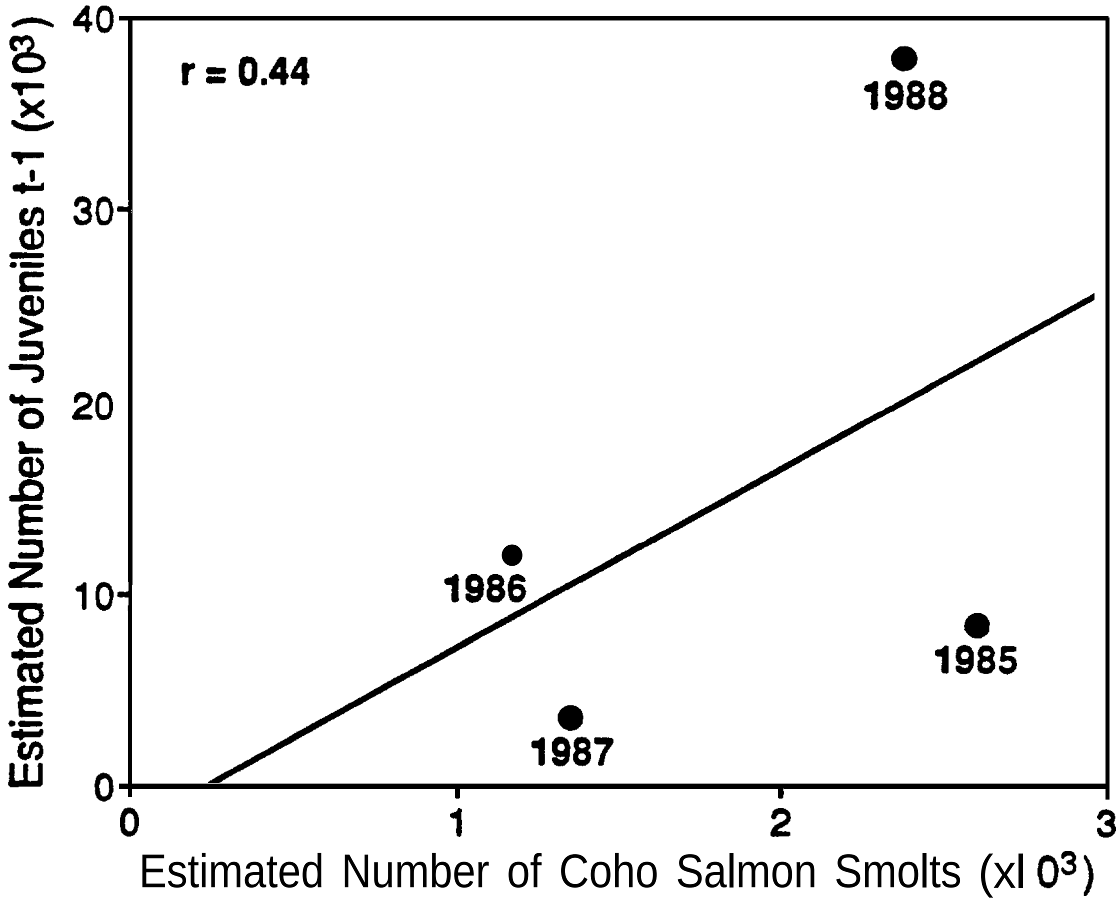

Figure 8. Relationship between estimated numbers of juvenile coho salmon in Fish Creek in summer and estimated amount of rearing habitat available in the'summer prior to migration.

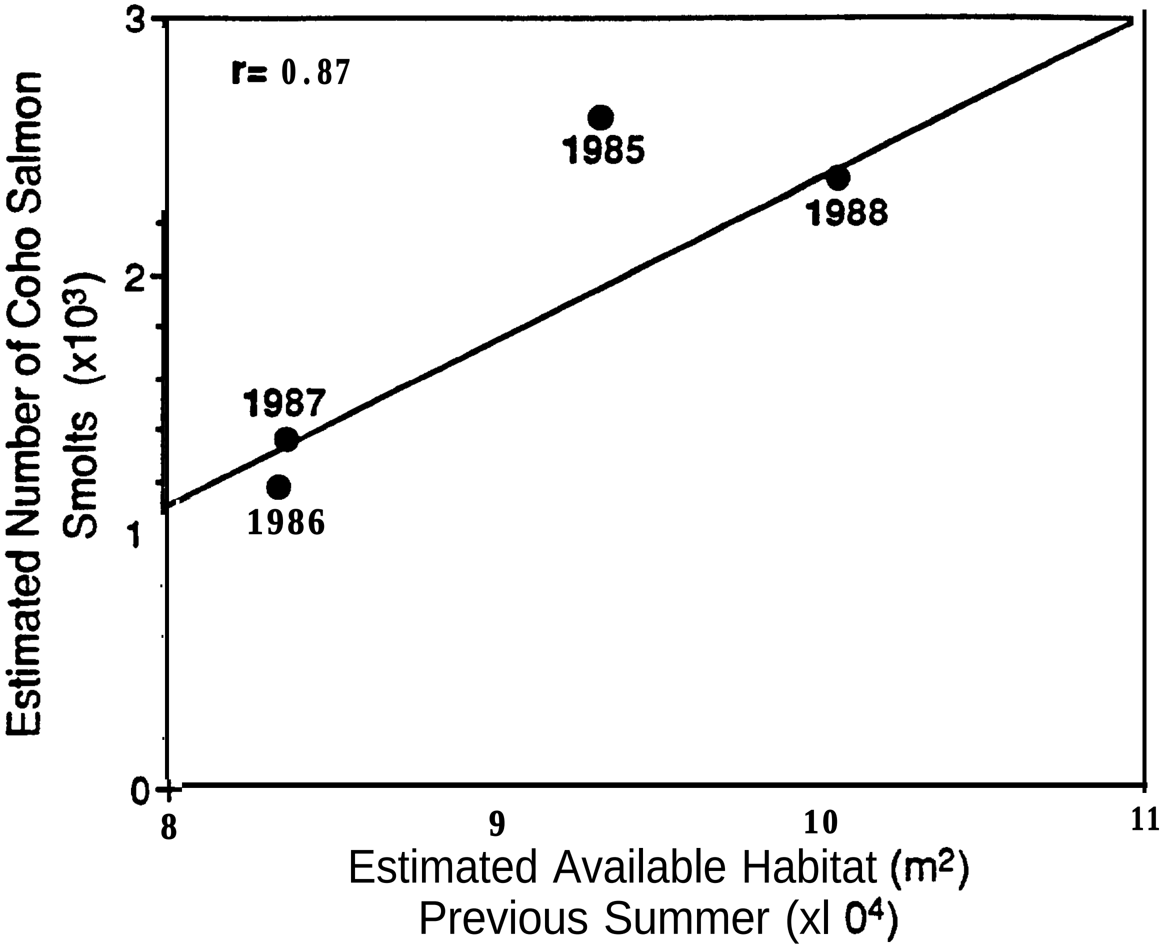

Figure 9. Relationship between estimated numbers of juvenile coho salmon in Fish Creek in summer and estimated numbers of coho salmon smolts leaving Fish Creek the following spring.

estimated to date (Table 5). Much of the work at Fish Creek was designed to develop complex pockets of habitat along the stream margins to provide winter habitat for coho salmon and other salmonids. It is not clear at present, however, whether this will succeed in enhancing production of coho salmon.

Off-channel rearing ponds. The most successful aspect of the Fish Creek program to date is the creation of the off-channel rearing ponds. In particular, the older east-side pond has made a significant contribution to total production of coho salmon (Table 5). The west-side pond, created in 1985, is not fully operational but based on the production of smolts in 1988 appears to have the potential to make a significant contribution to the total production of coho salmon.

Prior to 1988, the east-side pond contributed up to 50 percent of the total coho salmon smolts produced in Fish Creek (Table 5). The contribution was low in 1988, 8.7 percent (Table 5) because diseased fish were introduced to the pond and survival was extremely low. Based on the production of the pond in 1986 and 1987, Everest et al. (1987) calculated a positive cost:benefit ratio of 1.2/l to 1.6/l, depending on discount rates. Flow to the pond was stopped in 1988 to allow the pond to dry as much as possible and to minimize the chances of disease organisms from becoming permanently established. We assume that the pond will be as productive in the future as it was prior to 1988.

Steelhead Trout

Estimated production of steelhead trout smolts from mainstem Fish Creek was highly variable between 1985 and 1988 (Table 6). The mean number of smolts leaving Fish Creek annually was 5,489 **(±2382).** As observed with coho salmon, the variability occurred both during the period prior to intensive habitat modification (1985-86) and during the two years of habitat manipulations in lower and middle Fish Creek (1987-88). Estimated smolt numbers varied by about 100 percent between 1985 and 1986 (Table 6), suggesting that the production of steelhead trout smolts in Fish Creek may be naturally highly variable.

Smolt production was even more variable in the period of intensive habitat manipulations (Table 6). Production in 1987 was about 2.5 times greater than in 1988. Smolt production in 1988 was the lowest recorded to date. As with the analysis of the habitat manipulations on coho salmon, the large variability makes it impossible to discern the effects of the modification program to date. The effects may become clearer as more data are collected.

We have identified two factors that are strongly correlated with the estimated steelhead trout smolt production. One is the amount of habitat available during the summer low flow period. There is a strong correlation between available habitat during the summer low flow period during previous years and estimated numbers of steelhead trout smoits, r = 0.94 (Fig. 10). The estimated number of 1 + steelhead trout in Fish Creek the summer prior to smolt migration and the estimated number of steelhead trout smolts produced in Fish Creek are also strongly correlated, r = 0.89 (Fig. 11).

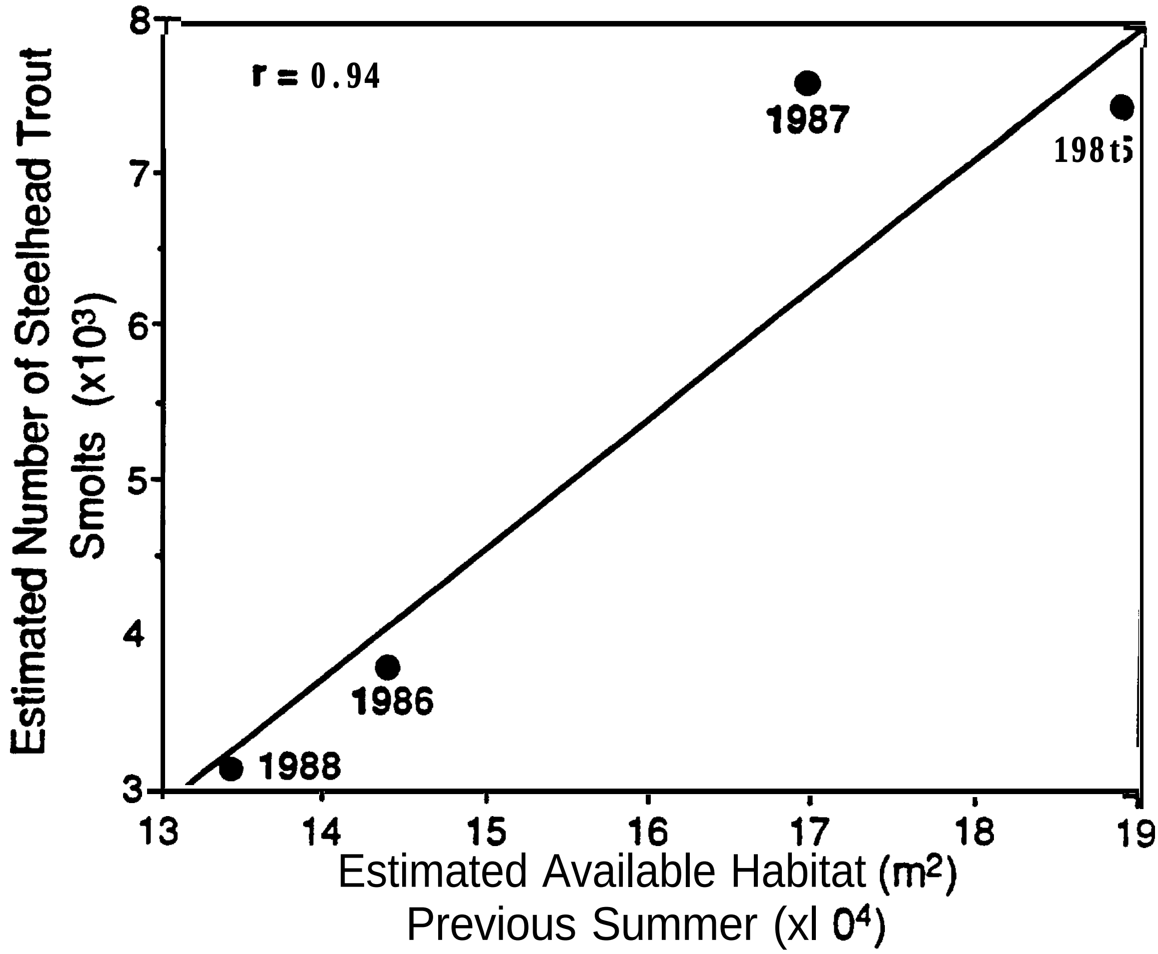

Figure 10. Relationship between estimated numbers of steelhead trout smolts leaving Fish Creek and, estimated amount of rearing habitat available the summer prior to migration.

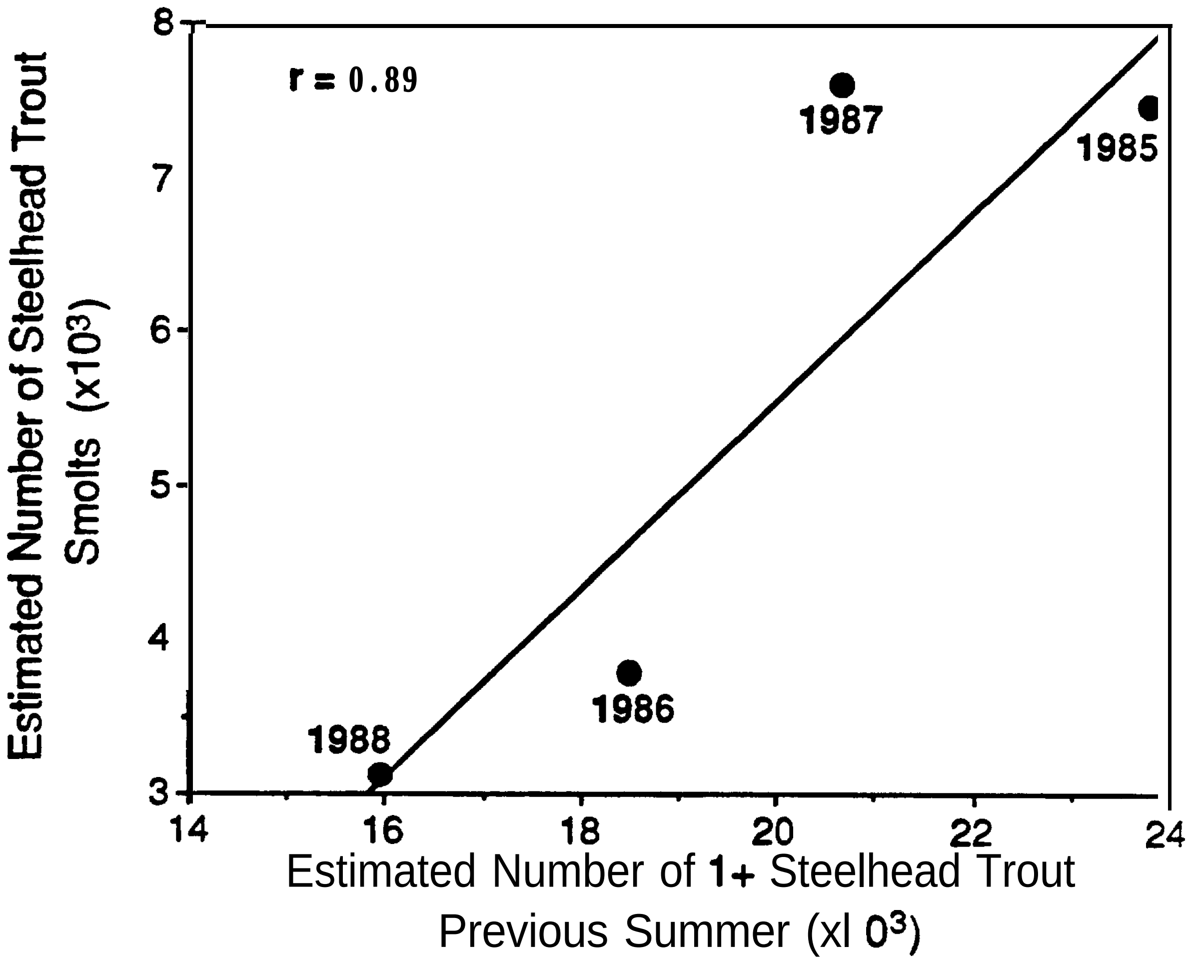

Figure 11. Relationship between estimated numbers of steelhead trout smolts leaving Fish Creek and estimated numbers of 1 + steelhead trout in Fish Creek the summer prior to migration.

SUMMARY AND CONCLUSIONS

(1). Evaluation of habitat modification efforts in 1988 focused on estimates of summer habitat availability and numbers of juvenile fish, and quantifying steelhead trout and coho salmon smolts.

(2). Availability of summer habitat varies directly with the water year; surface area of summer habitat can vary by 50 percent annually. About 12 percent more habitat was available in 1988 than in 1987.

(3). Coho salmon tagged in Fish Creek were captured in the off-shore commercial troll fishery at three locations along the central Oregon coast.

(4). All estimated populations of anadromous salmonids found in Fish Creek, except for 0+ juvenile steelhead trout, were lower in 1988 than in 1987. Estimated numbers of coho salmon and 1 + steelhead trout declined 90 percent and 9.5 percent, respectively, compared to 1987. No chinook salmon were found in Fish Creek in 1988. This contrasts sharply with 1987, when the largest numbers since the study began were observed. There was a 41 percent increase in 0+ steelhead trout compared to 1987. At this time, there are no obvious explanation for these results.

(5). Estimated numbers of coho salmon and steelhead trout smolts were lower in 1988 than 1987. Numbers were decreased 21 percent and 59 percent, respectively. A major factor influencing coho salmon was the drastic decline in production of the off-channel ponds. Survival of fish which were stocked in the ponds was very low because of bacterial kidney disease. Low over-winter survival was a major factor responsible for the low numbers steelhead trout smolts.

('3). Two factors that appear to be strongly correlated with steelhead smolt production are: 1) the amount of habitat available during the summer low flow period, and 2) the number of 1+ steelhead trout in Fish Creek the summer prior to smolt migration.

(7). Examination of trends from 1982 to the present, suggest that the intensive effort since 1985 appears to be influencing the composition of habitat in Fish Creek. There has been an increase in pools and glides, and the present composition is similar to conditions found prior to the 1964 flood.

(8). Our study to date suggests that production of salmon and steelhead juveniles and smolts in Fish Creek is quite variable.

(9). The large variability in smolt production makes it difficult to discern the short-term effects of the habitat modification program. The highest and lowest numbers have occurred since the work was completed. We believe that clearer trends will become apparent as more data are collected.

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Appendix 1. Recalculated areas of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1982

SPECIES	HABITAT	AREA (m2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m²	g/m²
COHO	Alcove	1,080	140	870	0.13	0.80
	Riffle	70,666	1,040	3,380	0.01	0.05
	Side channel	1,600	180	1,250	0.11	0.78
	Pool	8,110	290	2,850	0.04	0.35
	Beaver pond	190	260	1,200	1.37	6.34
	Total	81,330	1,910	9,550	0.02	0.12
CHINOOK	Alcove	1,080	10	70	0.01	0.06
	Riffle	70,350	0	0	--	--
	Side channel	1,600	0	0	--	--
	Pool	8,110	110	510	0.01	0.06
	Beaver pond	190	0	0	--	--
	Total	81,330	120	580	0.001	0.01
O+STHD	Alcove	2,270	2,200	5,010	0.97	2.21
	Riffle	138,590	75,240	211,660	0.54	1.60
	Side channel	4,250	5,100	12,870	1.20	3.03
	Pool	18,450	5,170	13,950	0.28	0.76
	Beaver pond	190	0	0	--	--
	Total	159,310	87,710	253,490	0.55	1.59
1 +STHD	Alcove	2,270	120	2,240	0.05	0.99
	Riffle	138,590	17,260	317,210	0.12	2.29
	Side channel	4,250	460	8,400	0.11	1.98
	Pool	18,450	3,840	84,930	0.21	4.60
	Beaver pond	190	0	0	--	--
	Total	159,310	21,680	412,780	0.14	2.59
ALL SALMONIDS	Alcove	2,270	2,470	8,190	1.09	3.61
	Riffle	138,590	93,540	542,250	0.67	3.91
	Side channel	4,250	5,740	22,520	1.35	5.03
	Pool	18,450	9,410	102,240	0.51	5.54
	Beaver pond	190	260	1,200	1.37	6.31
	Grand total	159,310	111,420	676,400	0.70	4.24

Appendix 1. (continued) Recalculated areas of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1983

SPECIES	HABITAT	AREA (m2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m²	g/m²
COHO	Alcove	1,170	220	1,080	0.19	0.92
	Riffle	104,820	5,340	29,680	0.05	0.28
	Side channel	2,230	130	380	0.06	0.17
	Pool	9,160	1,500	6,900	0.16	0.75
	Beaver pond	300	240	670	0.80	2.24
	Total	117,680	7,430	38,710	0.06	0.33
CHINOOK	Alcove	1,170	10	30	0.01	0.03
	Riffle	104,820	490	1,960	0.01	0.02
	Side channel	2,230	--	--	--	--
	Pool	9,160	640	2,950	0.07	0.32
	Beaver pond	300	--	--	--	--
	Total	117,680	1,140	4,940	0.01	0.04
O+STHD	Alcove	2,450	610	1,710	0.25	0.70
	Riffle	219,360	53,870	150,840	0.25	0.69
	Side channel	6,200	1,760	5,610	0.28	0.90
	Pool	20,850	3,780	12,470	0.18	0.60
	Beaver pond	300	10	30	0.03	0.11
	Total	249,169	60,030	170,660	0.24	0.68
1 +STHD	Alcove	2,450	90	2,370	0.04	0.97
	Riffle	219,360	23,760	427,140	0.11	1.95
	Side channel	6,200	340	5,780	0.05	0.93
	Pool	20,850	2,800	53,960	0.13	2.59
	Beaver pond	300	0	0	--	--
	Total	249,160	26,990	489,250	0.11	1.96
ALL SALMONIDS	Alcove	2,450	930	5,190	0.38	2.12
	Riffle	219,360	83,460	609,620	0.38	2.78
	Side channel	6,200	2,230	11,770	0.36	1.90
	Pool	20,850	8,720	76,280	0.42	3.66
	Beaver pond	300	250	700	0.83	2.33
	Grand Total	249,160	95,590	703,560	0.38	2.82

Appendix 1. (continued) Recalculated areas of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1984

SPECIES	HABITAT	AREA (m2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m²	g/m²
COHO	Alcove	1,080	630	2,360	0.28	2.19
	Riffle	81,610	3,310	12,740	0.04	0.16
	Side channel	2,000	1,920	6,240	0.96	3.12
	Pool	8,340	1,840	10,950	0.22	1.31
	Beaver pond	270	590	1,730	2.19	6.42
	Total	93,390	8,290	34,020	0.09	0.36
CHINOOK	Alcove	1,080	0	--	--	--
	Riffle	81,610	0	--	--	--
	Side channel	2,000	0	--	--	--
	Pool	8,340	280	3,140	0.03	0.38
	Beaver pond	270	10	130	0.04	0.48
	Total	93,390	290	3,270	0.003	0.04
O+STHD	Alcove	2,280	830	1,660	0.36	0.73
	Riffle	161,700	81,010	196,850	0.50	1.22
	Side channel	5,320	2,370	6,110	0.45	1.15
	Pool	19,180	3,850	10,240	0.28	0.53
	Beaver pond	270	0	0	--	--
	Total	188,750	88,060	214,860	0.47	1.14
1 +STHD	Alcove	2,280	110	3,360	0.05	1.47
	Riffle	161,420	18,420	405,240	0.12	2.51
	Side channel	5,320	440	7,220	0.08	1.36
	Pool	19,180	4,280	112,990	0.25	5.89
	Beaver pond	270	10	330	0.09	1.20
	Total	188,750	23,260	529,140	0.12	2.80
ALL SALMONIDS	Alcove	2,280	1,507	7,380	0.69	3.24
	Riffle	161,700	102,740	614,830	0.64	3.80
	Side channel	5,320	4,730	19,570	0.89	3.68
	Pool	19,180	10,250	137,320	0.53	7.15
	Beaver pond	270	610	2,190	2.26	8.11
	Grand total	188,750	119,900	781,290	0.64	4.14

Appendix 1. (continued) Area of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1985

SPECIES	HABITAT	AREA (m2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m²	g/m²
COHO	Glide	13,450	5,720	34,320	0.43	2.55
	Riffle	55,810	3,850	15,550	0.07	0.28
	Side channel	2,300	600	2,420	0.26	1.05
	Pool	11,840	1,550	9,300	0.13	0.79
	Beaver pond	190	260	1,570	1.37	8.28
	Total	83,590	11,980	63,160	0.14	0.76
CHINOOK	Glide	13,450	1,490	7,750	0.11	0.58
	Riffle	55,810	1,620	6,770	0.03	0.12
	Side channel	2,300	0	0	--	--
	Pool	11,840	1,240	6,450	0.10	0.54
	Beaver pond	190	0	0	--	--
	Total	83,590	4,350	20,970	0.05	0.25
O+STHD	Glide	21,030	20,270	46,620	0.96	2.21
	Riffle	93,770	72,960	174,370	0.78	1.86
	Side channel	2,580	2,260	4,270	0.70	1.66
	Pool	26,380	20,180	46,410	0.76	1.76
	Beaver pond	190	100	250	0.14	1.32
	Total	143,950	115,770	271,920	0.80	1.89
1 +STHD	Glide	21,030	1,800	36,380	0.09	1.74
	Riffle	93,770	12,880	262,490	0.14	2.80
	Side channel	2,580	230	4,310	0.09	1.67
	Pool	26,380	3,610	96,420	0.14	3.66
	Beaver pond	190	0	0	--	--
	Total	143,950	18,520	399,900	0.13	2.78
ALL SALMONIDS	Glide	21,030	29,280	125,370	1.39	5.96
	Riffle	93,770	91,310	459,180	0.97	4.90
	Side channel	2,580	3,090	11,000	1.20	4.26
	Pool	26,380	26,580	158,580	1.01	6.01
	Beaver pond	190	360	1,820	1.89	9.58
	Grand total	143,950	150,620	755,950	1.05	5.25

Appendix 1. (continued) Area of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1986

SPECIES	HABITAT	AREA (m2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m²	g/m²
COHO	Glide	13,750	2,170	9,100	0.16	0.66
	Riffle	62,940	40	160	0.001	0.003
	Side channel’	0	0	0	0.0	0.0
	Pool	7,170	1,350	7,130	0.18	0.99
	Beaver pond*	190	--	--	--	--
	Total	84,050	3,560	16,390	0.04	0.20
CHINOOK	Glide	13,750	100	420	0.01	0.03
	Riffle	62,940	0	0	0.00	0.0
	Side channel’	0	0	0	--	--
	Pool	7,170	100	940	0.01	--
	Beaver pond*	190	0	0	--	--
	Total	84,050	200	1,360	0.001	0.02
O+STHD	Glide	27,380	19,490	23,350	0.35	0.85
	Riffle	114,400	94,410	244,870	0.83	2.14
	Side channel’	0	0	--	0.00	0.0
	Pool	24,480	13,970	42,050	0.51	1.72
	Beaver pond*	190	--	--	--	--
	Total	166,450	117,870	310,270	0.70	1.86
1 +STHD	Glide	27,380	3,230	53,040	0.11	1.94
	Riffle	114,400	10,820	182,640	0.09	1.60
	Side channel’	0	--	--	0.00	0.0
	Pool	24,480	6,620	120,550	0.24	4.92
	Beaver pond*	190	--	--	--	--
	Total	166,450	20,670	356,230	0.12	2.14
ALL SALMONIDS	Glide	27,380	14,990	85,910	0.55	3.14
	Riffle	114,400	105,270	427,670	0.92	3.74
	Side channel’	0	0	0	0.00	0.0
	Pool	24,480	22,040	170,670	0.90	6.97
	Beaver pond*	190	--	--	--	--
	Grand total	166,450	123,300	684,250	0.74	4.11

[1]All side channels were dry in 1986.
[2]Beaver pond was not sampled for fish in 1986.

Appendix 1. (continued) Area of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK, SEPTEMBER 1987

SPECIES	HABITAT	AREA (m2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m²	g/m²
COHO	Glide	20,370	8,520	25,670	0.34	1.26
	Riffle	58,940	6,160	22,400	0.05	0.38
	Side channel[1]	940	--	--	--	--
	Pool	20,260	22,750	79,010	1.1	3.9
	Beaver pond	190	450	1,150	2.4	6.1
	Total	100,700	37,880	128,230	0.38	1.27
CHINOOK	Glide	20,370	1,450	7,740	0.07	0.38
	Riffle	58,940	1,640	11,200	0.03	0.19
	Side channel[1]	940	--	--	--	--
	Pool	20,260	3,200	18,440	0.16	0.91
	Beaver pond	190	0	0	0.00	0.00
	Total	100,700	6,290	37,380	0.06	0.37
0+STHD	Glide	23,980	15,230	43,400	0.64	1.81
	Riffle	79,700	21,010	69,340	0.26	0.87
	Side channel[1]	940	--	--	--	--
	Pool	29,660	17,150	52,500	0.58	1.77
	Beaver pond	190	10	30	0.04	0.15
	Total	134,470	53,400	165,270	0.40	1.23
1+STHD	Glide	23,980	3,360	59,950	0.13	2.50
	Riffle	79,700	6,760	119,550	0.07	1.50
	Side channel[1]	940	--	--		--
	Pool	29,660	5,850	114,700	0.20	3.87
	Beaver pond	190	0[2]	0[2]		
	Total	134,470	15,970	294,280	0.12	2.20
ALL SALMONIDS	Glide	23,980	28,560	136,760	1.18	5.68
	Riffle	79,700	35,570	222,490	0.45	2.79
	Side channel[1]	940	--		--	
	Pool	29,660	48,950	264,730	1.65	8.93
	Beaver pond*	190	460	1,180	2.42	6.21
	Grand total	134,470	113,540	625,160	0.84	4.65

[1]All side channels were nearly dry in 1987 and were not sampled for fish.
*One 1+ steelhead trout captured in beaver pond.

Appendix 1. (continued) Areas of rearing habitats in Fish Creek and associated salmonid densities and biomass.

FISH CREEK SEPTEMBER 1988

SPECIES	HABITAT	AREA (m2) IN SYSTEM	ESTIMATED NUMBER OF FISH BY HABITAT	ESTIMATED BIOMASS (g) OF FISH BY HABITAT	#/m²	g/m*
COHO	Glide	22,180	430	2,000	0.02	0.09
	Riffle	57,450	190	14,940	0.003	0.26
	Side channel'	950	10	380	0.01	0.40
	Pool	21,370	2,920	23,290	0.14	1.09
	Beaver pond	190	0	0	0	0
	Total	102,140	3,550	40,610	0.03	0.40
CHINOOK	Glide	22,180	0	0	0.00	0
	Riffle	57,450	0	0	0.00	0
	Side channel'	950	--	--	--	--
	Pool	21,370	0	0	0.00	0
	Beaver pond	190	0	0	0.00	0
	Total	102,140	0	0	0.001	0
O+STHD	Glide	33,330	25,210	77,020	0.76	2.31
	Riffle	84,970	32,390	146,930	0.38	1.73
	Side channel'	1,050	270	2,050	0.25	1.96
	Pool	32,590	21,630	71,740	0.66	2.20
	Beaver pond	190	0	0	0.00	0
	Total	152,170	79,500	297,800	0.52	1.96
1 +STHD	Glide	33,370	2,880	146,570	0.09	4.39
	Riffle	84,970	6,540	37,927	0.08	4.46
	Side channel'	1,050	20	5,440	0.02	5.18
	Pool	32,590	4,990	25,663	0.15	7.87
	Beaver pond	190	0	0	0.00	0
	Total	152,170	14,460	787,910	0.10	5.18
ALL SALMONIDS	Glide	33,370	28,520	225,590	0.85	6.76
	Riffle	84,970	39,150	541,190	0.46	6.37
	Side channel'	1,050	300	7,880	0.29	7.50
	Pool	32,590	29,540	351,660	0.91	10.79
	Beaver pond*	190	0	0	0.00	0
	Grand Total	159,310	111,420	676,400	0.70	4.24

[1] All side channels were nearly dry in 1988 and were not sampled for fish.
[2] One 1 + steelhead trout captured in beaver pond.